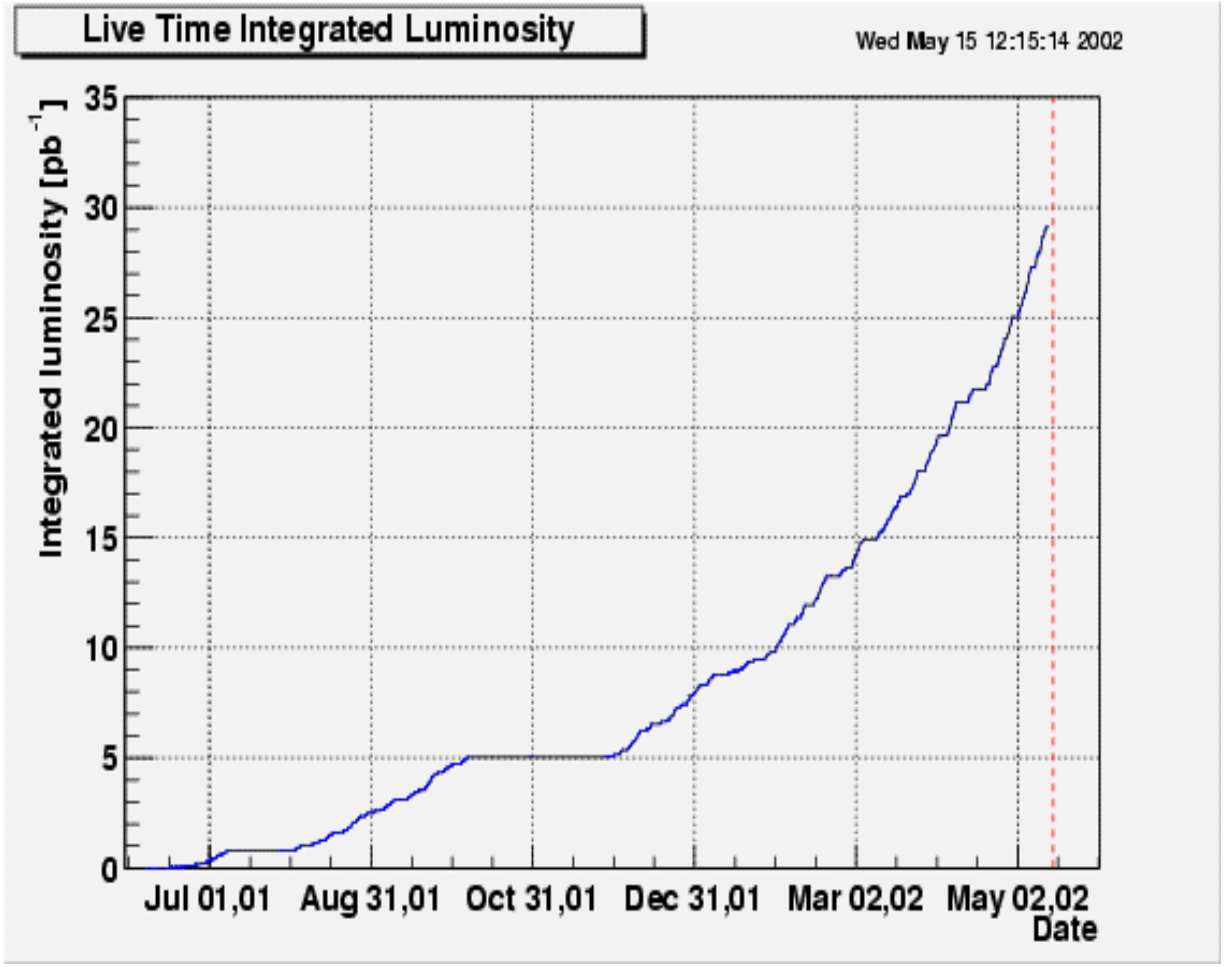
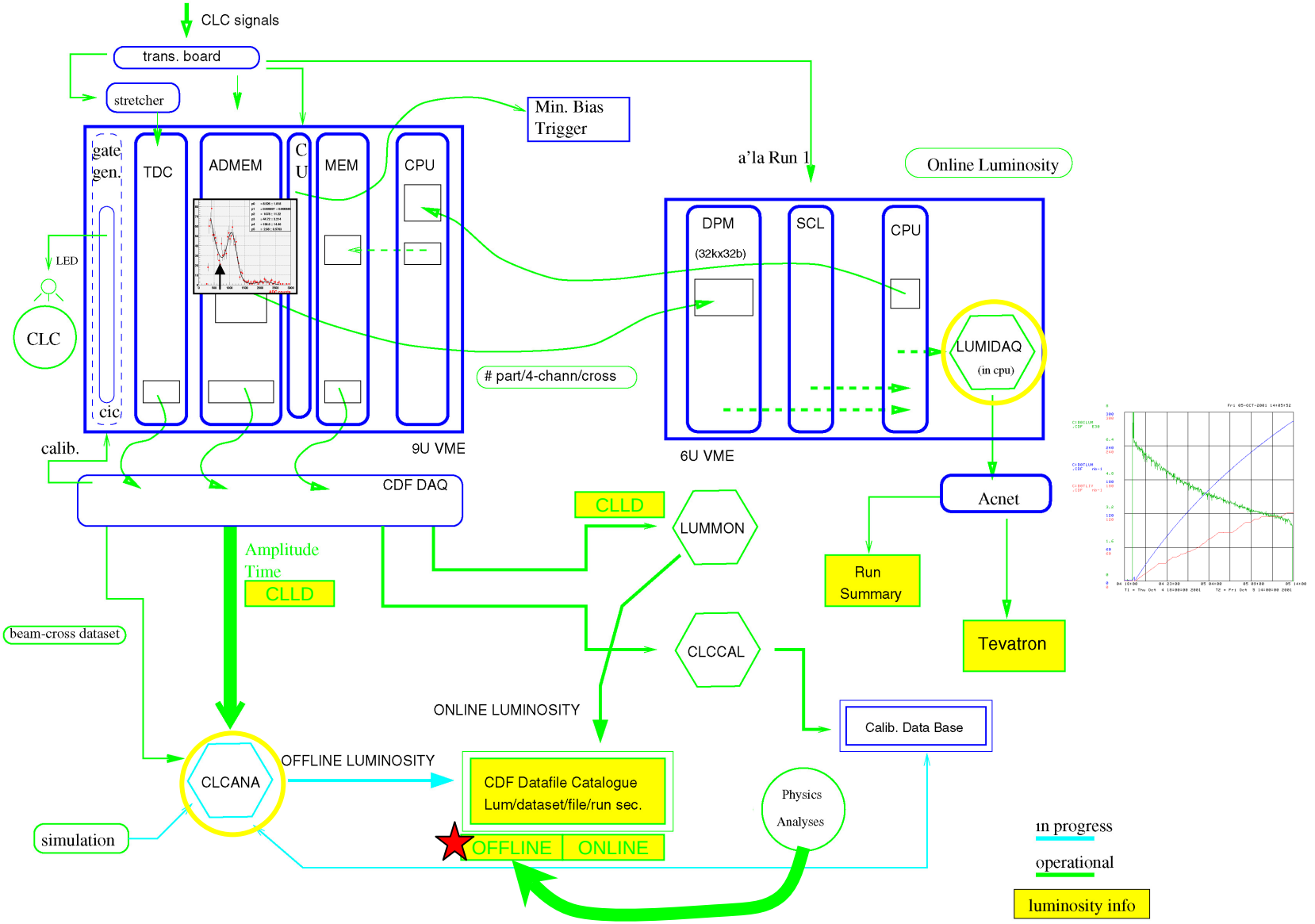
Status of the Run II Luminosity Measurement



- ❖ Lum. Information
  - Accessing it
- ❖ Measurements
  - Uncertainties
  - Cross-checks
- ❖ Plans

- Luminosity Group
  - D. Acosta
  - S. Klimenko
  - J. Konigsberg
  - A. Korytov
  - G. Mitselmakher
  - V. Necula
  - A. Pronko
  - A. Sukhanov
  - D. Tsybychev
  - S.M. Wang
  - M. Dittmar
  - A-S Nicollerat

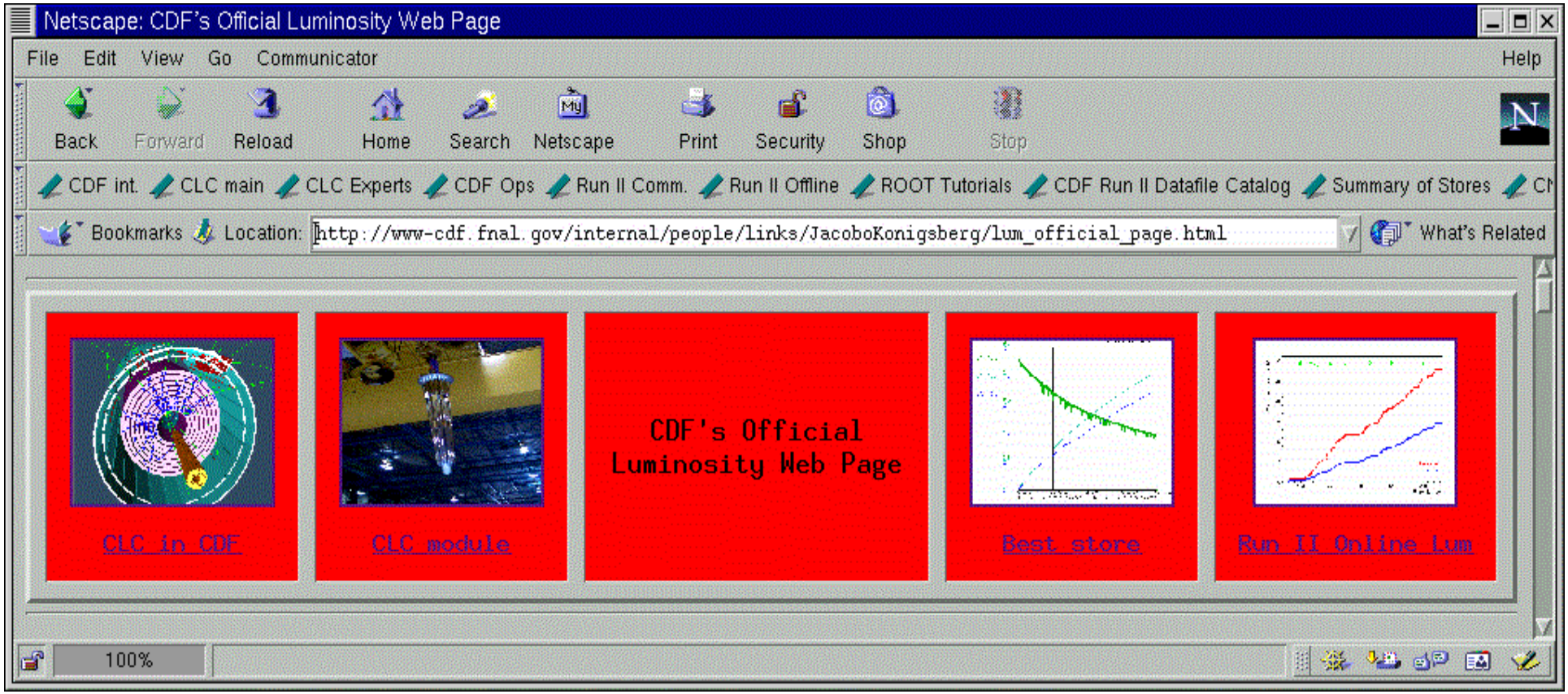
Luminosity Information



Official Luminosity Web Page

Access from cdf/internal→ physics in progress→ Luminosity:

http://cdfsga.fnal.gov/internal/physics/physics.html



LumWeb Page (cont.)

Overview:

- The Luminosity at CDF is measured both ONLINE and OFFLINE with the Cherenkov Luminosity Counters "CLC"

- The ONLINE luminosity shows up on ACNET in real-time and takes into account multiple interactions automatically but does not include further possible corrections or refinements which are done OFFLINE. These ONLINE numbers, used for example in the "runSummary" database and in the "Summary of Stores" page by the ops. managers and need to be considered with this caveat taken into account. All that said, we try to keep the ONLINE measurements very close to the OFFLINE.

- The OFFICIAL luminosity numbers are provided by the Luminosity Group and are stored, by Run Section, in the OFFLINE part of the "Data File Catalogue (DFC)"

  - These Run Section entries are filled with the latest [best understood] version of the luminosity calculation and may be improved over time.
  - Luminosity entries in the DFC for Files, Filesets and Datasets are filled by the Data Handling/DFC group (D. Litvintsev) by summing over the appropriate Run Sections. The Luminosity Group is not responsible for keeping track of which Run Sections belong to which file or dataset.

- Below we show how to access this DFC luminosity information at a basic level.

- Below we also present a table that contains details of what period of stores has been processed offline and what is the luminosity version that applies to that period. Click on the version number to get all details on the methodology used in the lum calculation.

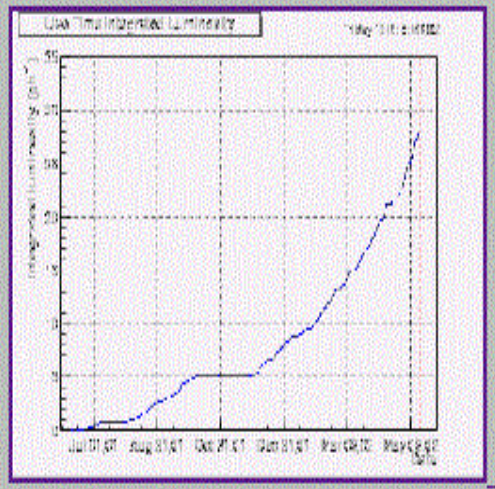
- The ONLINE entries in the Data File Catalogue are not to be considered OFFICIAL. They are estimated online, by LumMon, without full corrections, and may contain holes or other problems. They are intended for expert's use only.

- EVERY CDF EVENT also contains the ONLINE luminosity information. Both the avg. instantaneous luminosity and the integrated luminosity, up to that event, are available. Consumers such as XMON access this information online. Offline one can use this piece of code to "unpack" the information: "CLLD access"

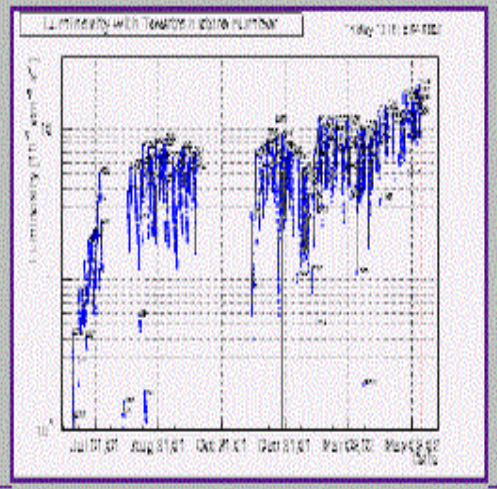
LumWeb Page (cont.)

The Big Picture:

- These plots show the UP-TO-DATE online ACNET Luminosity for runs which have Physics* in the RUNTYPE and Beam data in the DATATYPE (thanks to Yuji Takeuchi !)



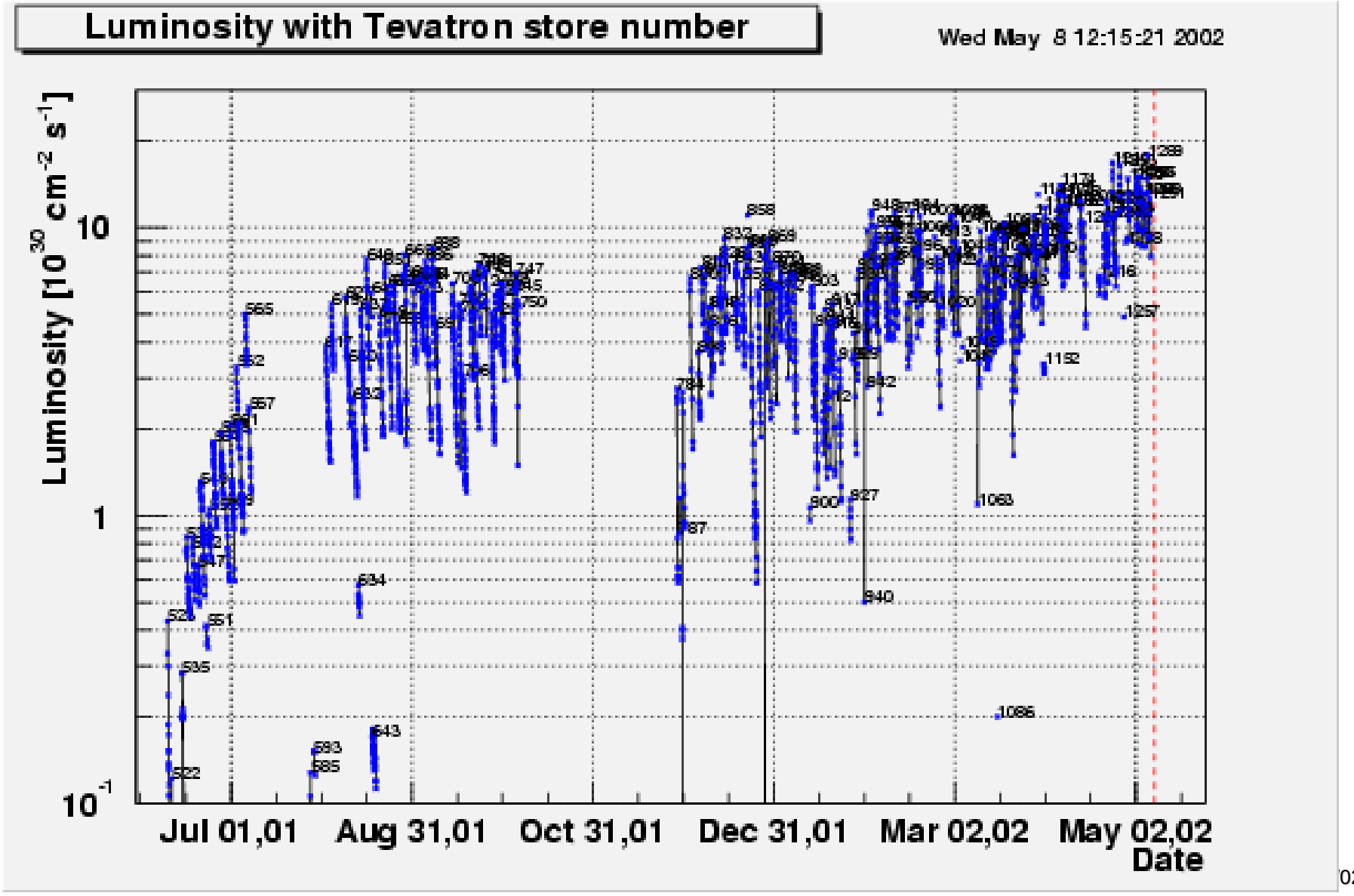
Live integrated Lum vs time



Avg. Inst. Lum per store

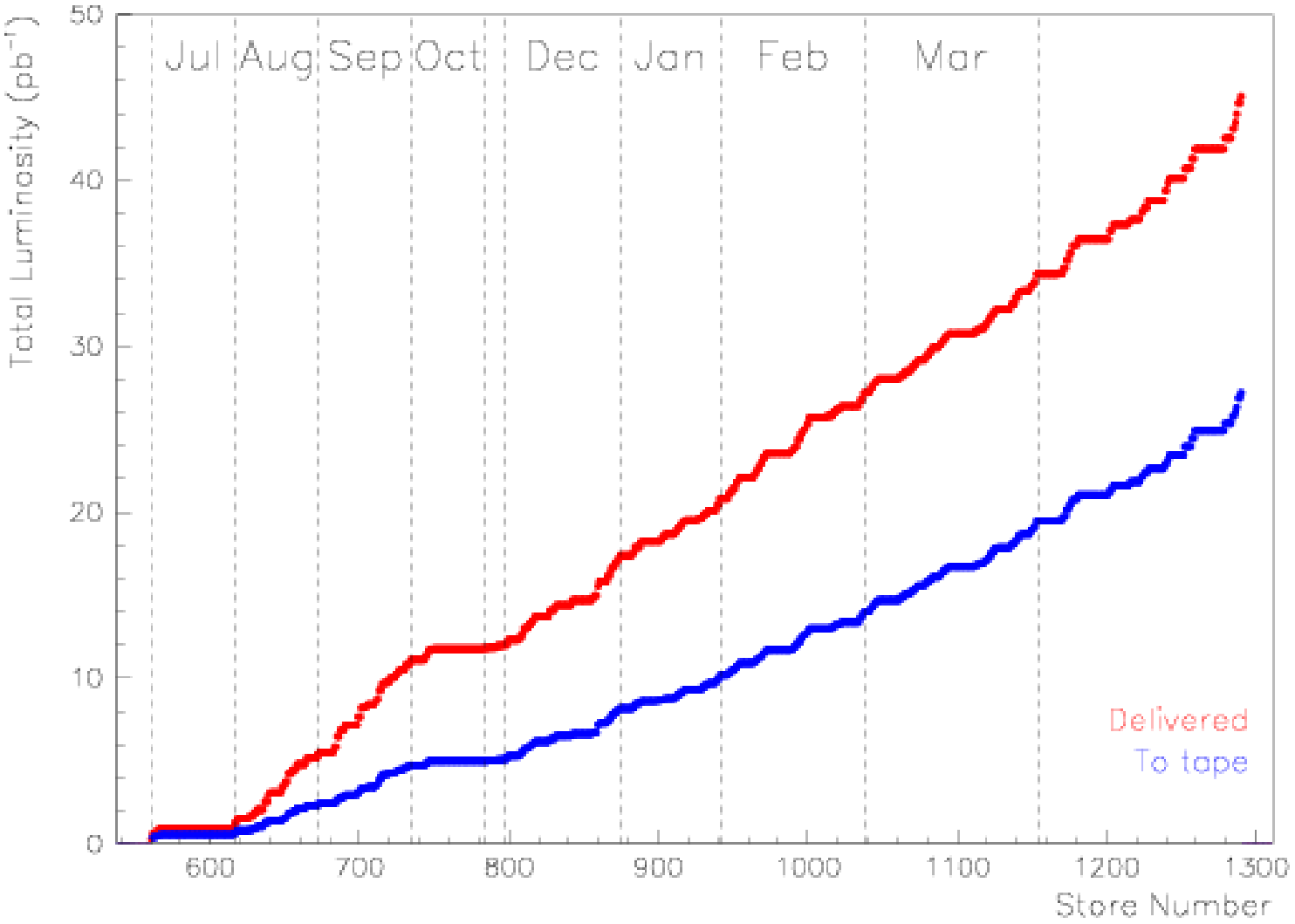
- Plots by store for the online ACNET Luminosity (from the ops manager's store page: "Summary of Stores")
  - By store number: duration | initial luminosity | integrated luminosity | efficiency | Run II luminosity
  - Distributions: duration | initial luminosity | integrated luminosity | efficiency

100%

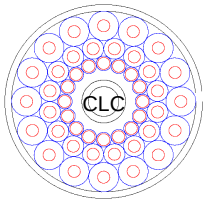

Luminosity with Tevatron store number
Wed May 8 12:15:21 2002
Luminosity [10^30 cm^-2 s^-1]
10
1
10^-1
Jul 01,01
Aug 31,01
Oct 31,01
Dec 31,01
Mar 02,02
May 02,02
Date

02

Integrated Lum



J. Konigsberg
Joint Physics meet 05/17/02



LumWeb Page (cont.)

Luminosity Access for Datasets:

- The FIRST STEP in finding the integrated luminosity for a given dataset is to generate a LOG FILE with a list of runs and run-sections that correspond to the ORIGINAL POOL from which this dataset was created. This is done through the AC++ Data Handling Input module as follows:

  - AC++> Mod Talk DHInput
  - setInput log=your_log_file_name

- The SECOND STEP consists in running a standalone program that input this log file and that sums all the corresponding entries in the Data File Catalogue:

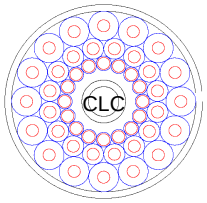
  - fcdfsgi2> lumsum.pl offline your_log_file_name

This program has been created by the Data Handling group (Eric Wicklund) and runs on FCDFSGI2 after the standard setups:

- fcdsgi2> source ~cdfsoft/cdf2.cshrc
- fcdfsgi2> setup cdfsoft2 4.2.0 (or any other version)

- IMPORTANT THINGS TO KEEP IN MIND:

  - When the integrated luminosity for a SECONDARY DATASET is calculated, the luminosity for ALL run-sections from which the PRIMARY DATASET was obtained should be taken into account.
  - When events are filtered out in data processing, if no events are left from a given run-section, the DH makes sure that a special empty run-section record (ERS) is added to the output data file for this run-section.
  - If "bad runs" or "low luminosity" runs are thrown out using the AC++ DHInput "selectEvents" command, the corresponding ERS record WILL NOT be created and these run-sections will not contribute to the total luminosity, as it should be the case.
  - If "bad runs" or "low luminosity runs" are thrown out by any AC++ analysis module the ERS record WILL BE created and kept and this will result in an overestimate of the luminosity.



LumSum Example

- LumSum log-file-name

- # Data processing log for the process PID 59925341 generated by DHLogger
- OIF /cdf/data05/s7/data_val/HighPtElectrons/ElectronSample_4238.dat
- R 126998
- S 0 38
- R 126999
- S 0 0
- S 8 112
- R 127016
- S 0 11
- R 127017
- S 0 10
- S 13 13
- S 15 19
- S 24 25
- .
- .
- .
- CIF /cdf/data05/s7/data_val/HighPtElectrons/ElectronSample_4238.dat
- OIF /cdf/data05/s7/data_val/HighPtElectrons/ElectronSample_4238.dat_1
- R 127023
- S 24 24
- .
- .
- .
- OIF /cdf/data05/s7/data_val/HighPtElectrons/ElectronSample_4238.dat_1
- .
- .
- .
- CIF /cdf/data06/s2/top/HighPtElectrons/ElectronSample_4295.dat_1

Lum Web page (cont.)

Official Luminosity Status in the Offline Data File Catalogue:

Period covered	1st Store <---> last Store	Latest Offline Luminosity Version
Aug 8th, 2001 <---> Mar 7th, 2002	622 <---> 1048	V_1.0
Mar 8th, 2002 <---> Mar 31st, 2002	1063 <---> 1150	V_1.0
Mar 31st, 2002 <--->	1152 <--->	N.A.

click

Luminosity V_1.0

- **Procedure:**
  - Based on the Online "hit counting" measurements done in the standalone CLC 6U crate which are read out into the CLLD bank
  - Lummon looks at the CLLD bank for events within 1 run section and takes the difference in live integrated luminosity between the 1st and last event to calculate the total integrated luminosity per run section. This value is then entered into the Online Luminosity column in the CDF II Datafile Catalogue.
  - We apply corrections to the Datafile Catalogue Online values, as described below, and fill the Datafile Catalogue Offline values.
    --> These Offline values are what users should access to calculate their dataset luminosity
  - We estimate the uncertainty in the total integrated luminosity for this version to be +/- 10% dominated by the absolute nromalization. This will be reduced in future versions with better MC simulation and further data studies.

- **Details on the Online "hit counting method" :**
  - Used the two CLC outer layers
  - Used Xilinx code with 500 ADC counts as the hit counting threshold
  - Required at least one hit per CLC module (East/West) in coincidence before counting
  - Used the following calculation: Lum = (f / Sigma_clc) * (Nhit / <Nhit>1)
  - f = tevatron's frequency = 36/(159*132 ns) = 1.715 MHz
  - Nhit = measured number of hits in a time period of ?????seconds/periods???
  - Sigma_clc = effective CLC cross section for an East-West coincidence (500 ADC counts)
  - <Nhit>1 = Avg. number of hits (East+West) in a single p=pbar interaction
  - We used the following values for Sigma_clc and <Nhit>1:
    - For 122255 < run < 126686 :
      <Nhit>1= 13.8 and Sigma_clc = 36.5 mb
    - For run .ge. 126686 :
      <Nhit>1 = 16 and Sigma_clc = 37.78 mb

Version 1.0 corrections

- **Corrections to the Online measurement:**
  - Filled gaps for run sections with zero Online luminosity due to Lummon failure
    - If for a given run more than 10% of the runsections in the Online Datafile Catalogue were zero then the Offline value of these runsections is set such that the total run luminosity is in agreement with the ACNET value (taken from the Run Configuration database). This happened for 25% of the runs that had a luminosity greater than 1 nb in ACNET.
    - If less than 10% of the runsections are zero we used a linear interpolation from adjacent non-zero runsections to compute the Offline luminosity for these runsections. If the run starts(ends) with runsections having zero luminosity then these are set to the value of the first(last) non-zero runsection.
  - For runs between 122255 and 126686 (between July 31st, 2001 and Sept 14th, 2001) we had an effective cross section such that the Online luminosity was measured 20% higher than it should have been.
    - We multiplied the Online Data catalogue values by 0.83 for these runs
  - Correction due to CSL not sending all events to Lummon
    - Lummon needs the first and last event of a runsection to calculate the full integrated luminosity. The CSL in many cases does not send these events and on average Lummon underestimates the luminosity by 2%.
  - Correction due to PMT gain drift between Sept 14, 2001, and Oct 6, 2001
    - The effective CLC cross-section and the number of hits per single interaction change if the PMT gain changes (due to the fixed Xilinx thresholds in the Online measurement). Offline corrected for this by looking at the single particle peak and applying thresholds relative to these peaks. We find a correction in the form of: L_offline = (1.035 + 0.0062 * t [days]) * L_online

Lum Web page (cont.)

Relevant Documents:

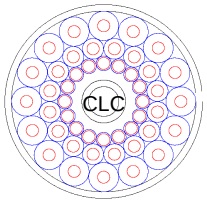
- "Luminosity for Aug-Oct 2001 - Jaco Konigsberg: presentation at CDF meet. 13-dec-2001
  - Slide show
  - PDF file
- "Luminosity Monitor Based on Cherenkov Counters for P-Pbar Colliders"
  - Nucl. Instr. & Meth. A441 (366-373), 2000 - PS file (cdf-5003)
- "The CDF Run II Luminosity Monitor"
  - Nucl. Instr. & Meth. A461 9540-544), 2001 - PS file (cdf-5559)"
- "The Performance of the CDF Luminosity Monitor"
  Submitted to NIM, May 2002 - PS file
- "A first look at the CLC Luminosity measurements"
  CDF-XXXX ...Note in preparation

Luminosity using W and Z production:

- April 30th, 2002, presentation: Michael Dittmar & Anne-Sylvie Nicollerat
  - PS file, part 1
  - PS file, part 2
- April 30th, 2002, presentation: Valentin Necula
  - PS file

Jaco Konigsberg (last update May 14, 2002) -- konigsberg@fnal.gov

100%



DFC offline luminosity

- Use online lum (from LumMon) and make some corrections:
  - ***Online has acceptance adjustments for gain changes but not continuous***
    - → **Offline has a smoother acceptance correction**
    - → **Estimate < 2% uncertainty**
    - → **This uncertainty can be made negligible with automated offline analysis**
  - ***Online has some gaps due to LumMon crashing***
    - → **Interpolate for holes**
    - → **<10% holes and <2% interpolation error → < 0.2% uncertainty**
  - ***CSL misses start of run section – end of run section***
    - → **Systematically 1-2% low lum in LumMon**
    - → **Correct using ACNET**
    - → **Uncertainty in the correction < 0.5%**
- Assign 2% upper bound on the uncertainty for the online → offline transfer
- Most will go away with full, automated, offline reconstruction

Lum Measurements Methods

- For any luminosity measurement method w/CLC
  - *For a defined selection criteria* $\{\alpha\}$ *for a p-pbar interaction to be registered in the CLC :*

$$\tilde{\mu}_\alpha \cdot f_{BC} = \sigma_{in} \cdot \varepsilon_\alpha^{clc} \cdot L$$

$\tilde{\mu}_\alpha$ = avg. # of int. $\{\alpha\}$ / bunch crossing

f_{BC} = bunch crossing frequency

L = inst. luminosity

$\sigma_\alpha^{clc} \equiv \sigma_{in} \cdot \varepsilon_\alpha^{clc}$ (effective σ)

- Define a collision $\{\alpha\}$
  - *{ >0 hits in E} .and. { > 0 hits in W} with amplitude > A_o*
    - *Online has fixed thresholds*
    - *Offline we can normalize to single particle peak (spp)*
  - *require hits to be in-time*
    - *Online can have gates*
    - *Offline can cut tighter*

Hit Counting Method

$$L = \frac{f_{BC}}{\sigma_{in} \cdot \varepsilon_{\alpha}} \cdot \frac{\langle N_H \rangle_{\alpha}}{\langle N_H^1 \rangle_{\alpha}}$$

$\langle N_H^1 \rangle_{\alpha}$ = avg. # hits for a single p-pbar interaction.

Measured at low luminosity from 0-bias data

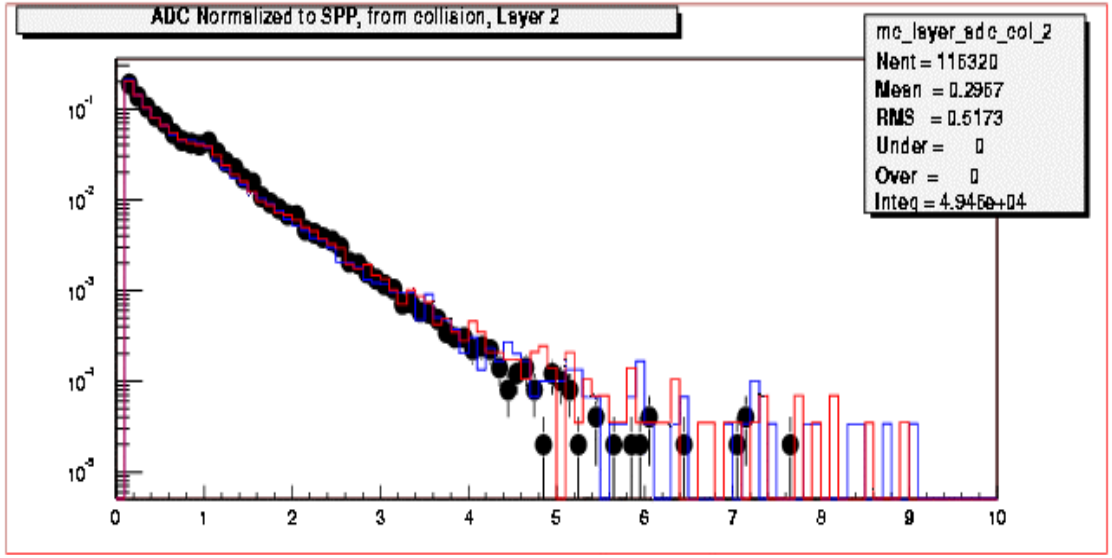
$\langle N_H \rangle_{\alpha}$ = measured avg. # hits/bunch crossing

- Uncertainty in measurement
  - *From ε_{α}*
  - *From $\langle N_H \rangle$*
- Uncertainty in the inelastic cross-section value
  - *From CDF measurement*
  - *Compared to E810 measurement ?*
  - *Use W→lepton,nu to "renormalize"*
- Have preliminary estimates of uncertainties

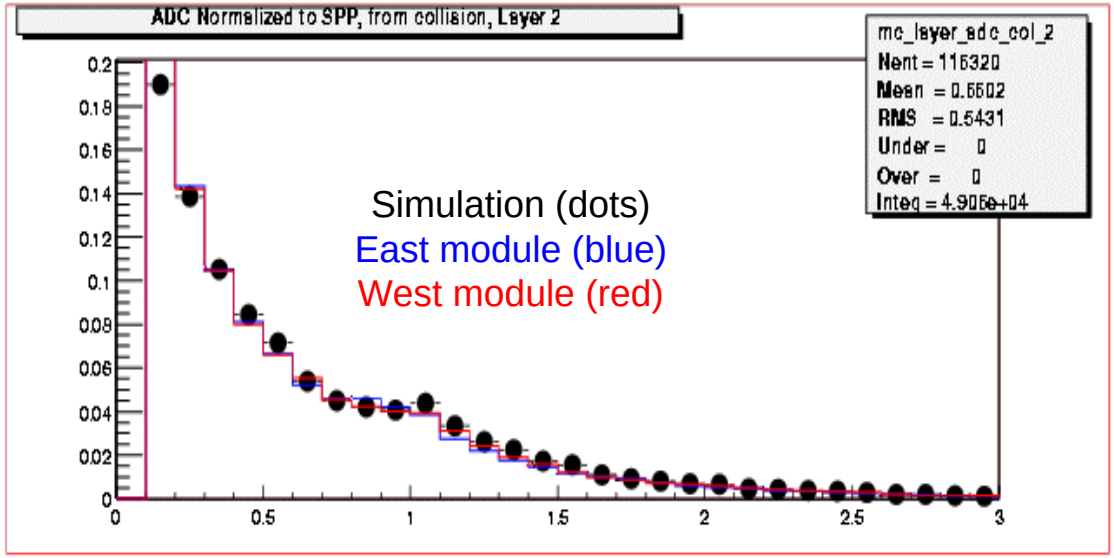
Estimating ε_α from CLC simulation

- Using CLC MC simulation alone:
  - ☑ *Need all material in simulation*
  - ☑ *Need full CLC simulation*
  - ☑ *Make sure data and simulation are excellently matched…*
    - →**Need correct generator [MBR is baseline]**
    - →**Make sure the mix of hard-core and diffractive processes is right**
  - *Figures of merit:*
    - →**Amplitude distributions**
    - →**Hit multiplicity distributions**
    - →**For all layers separately (“η” dependence)**
  - ☑ *Understand the uncertainty…*

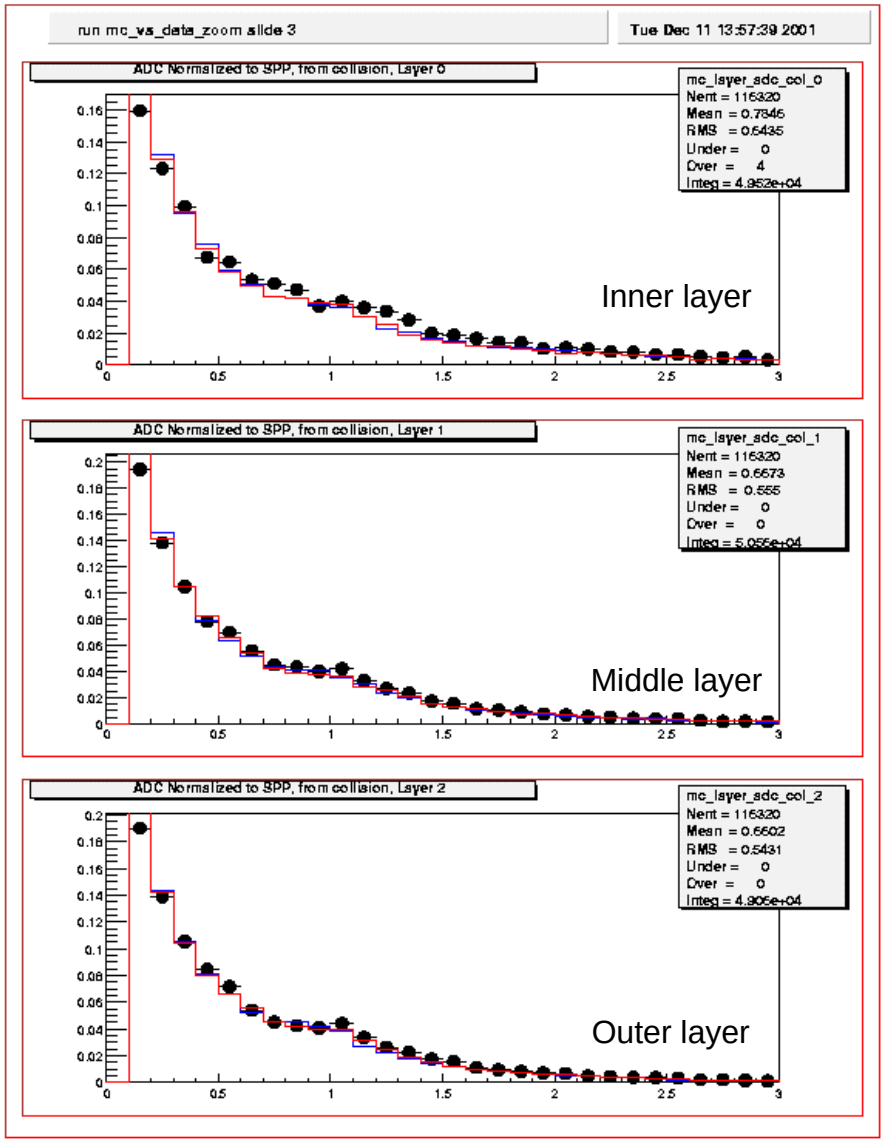
CLC amplitude distribution: data vs. sim

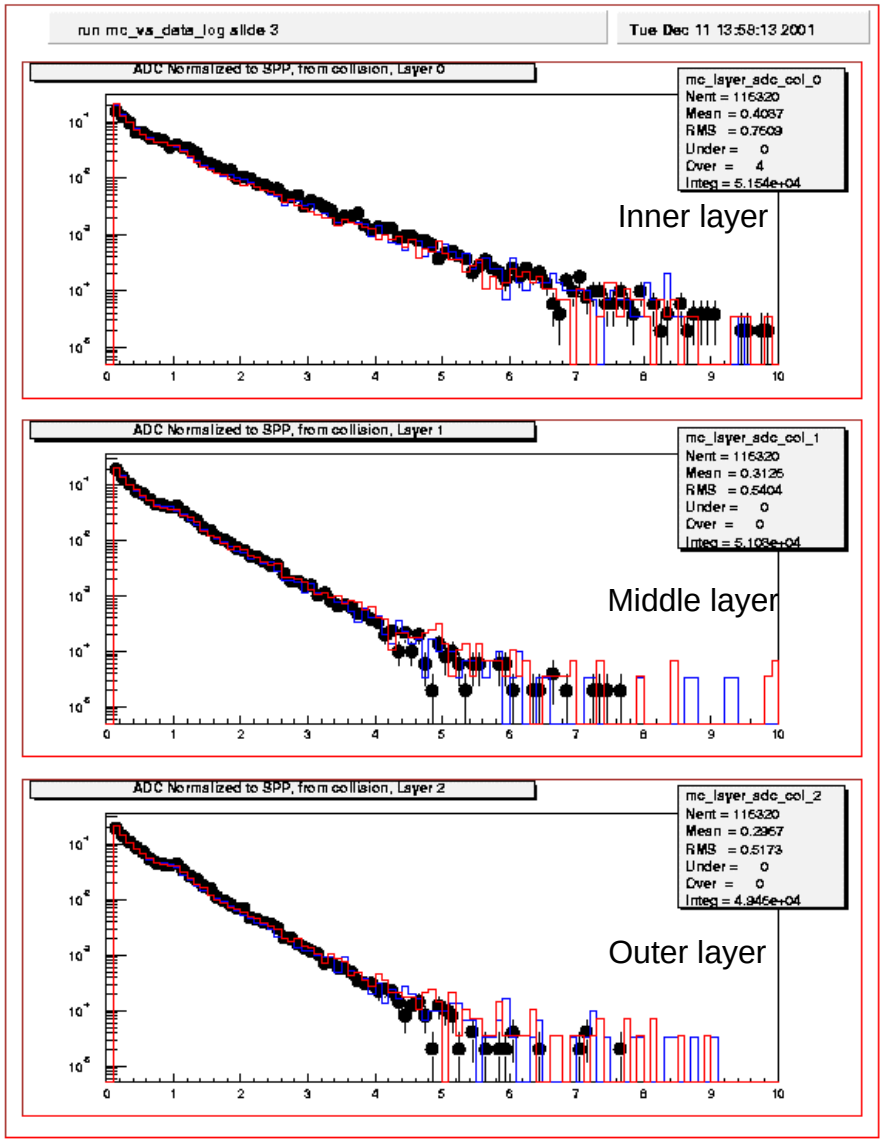


All layers

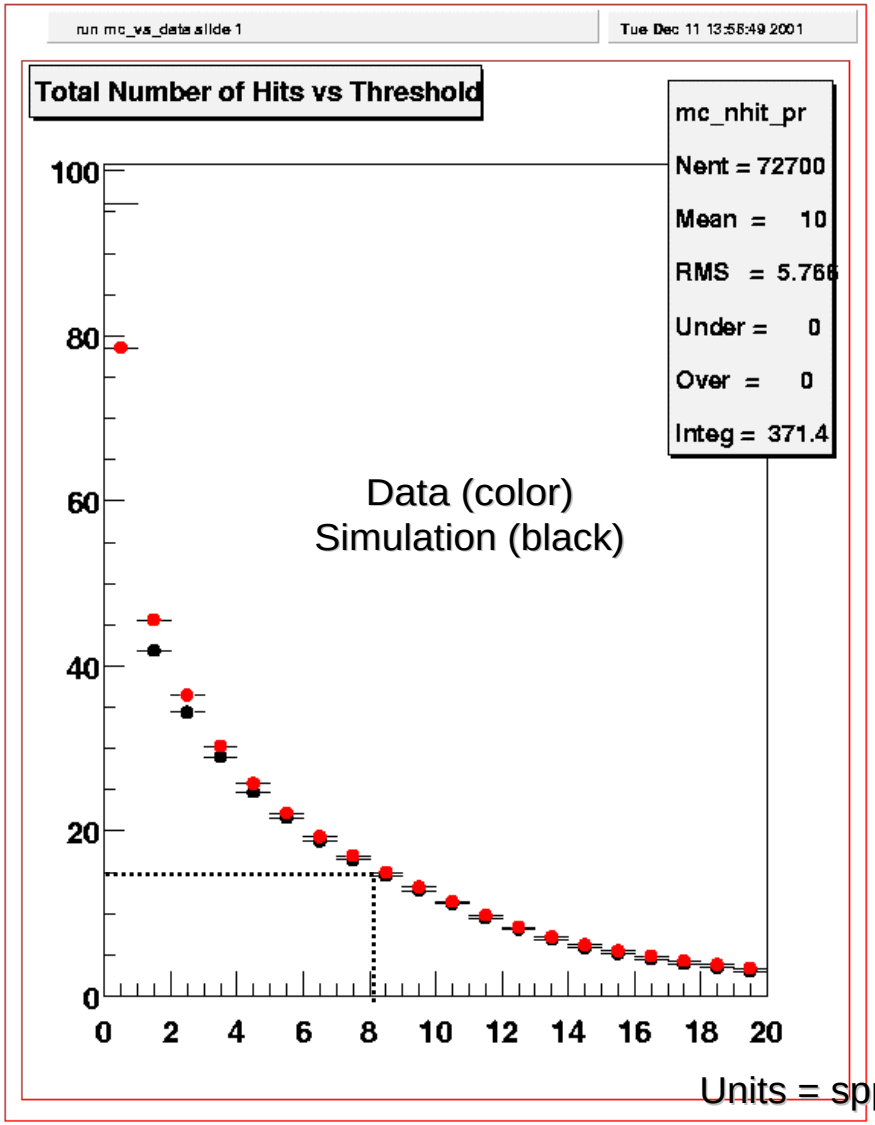


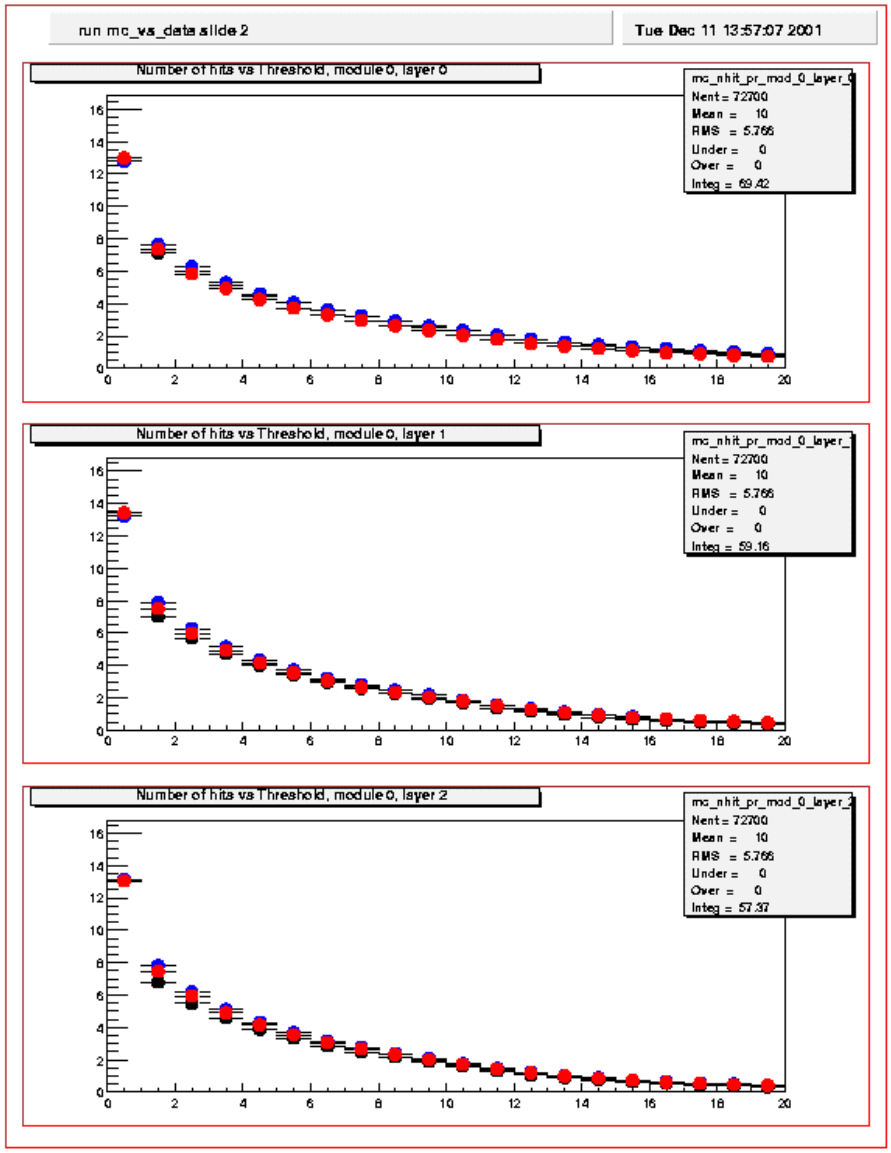
Amplitude distribution by layer: data vs. sim.





CLC <occupancy> vs. threshold

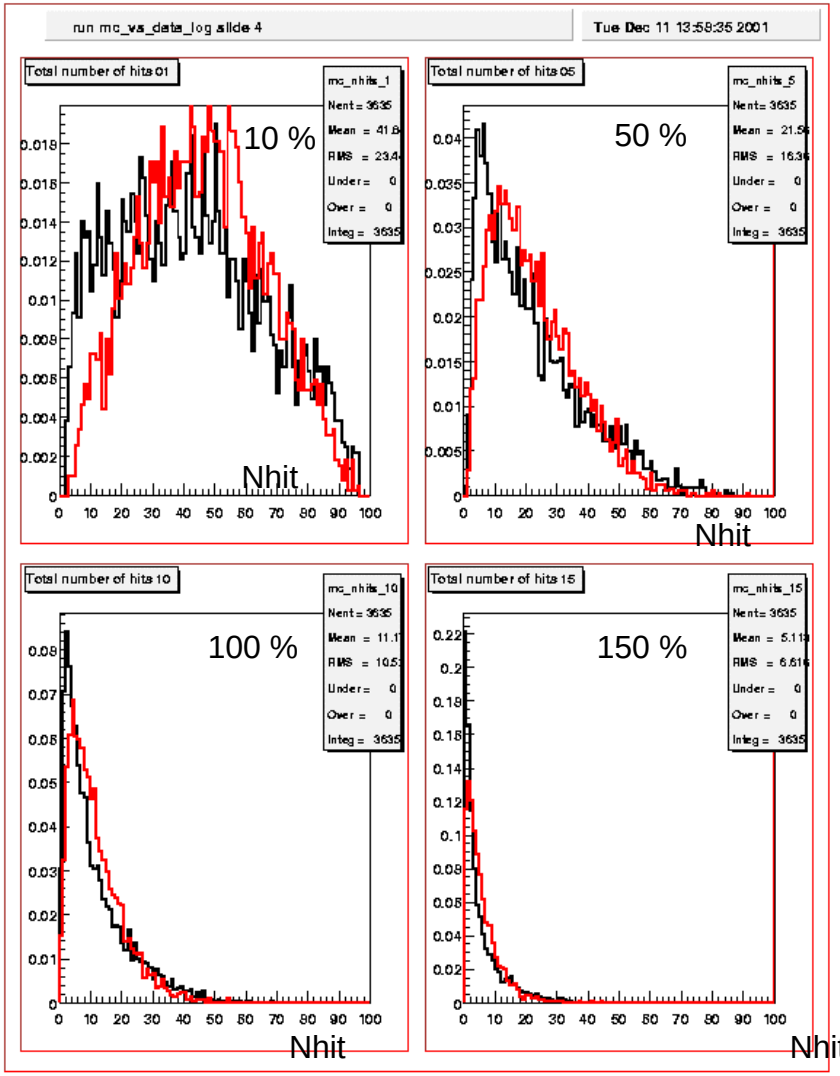




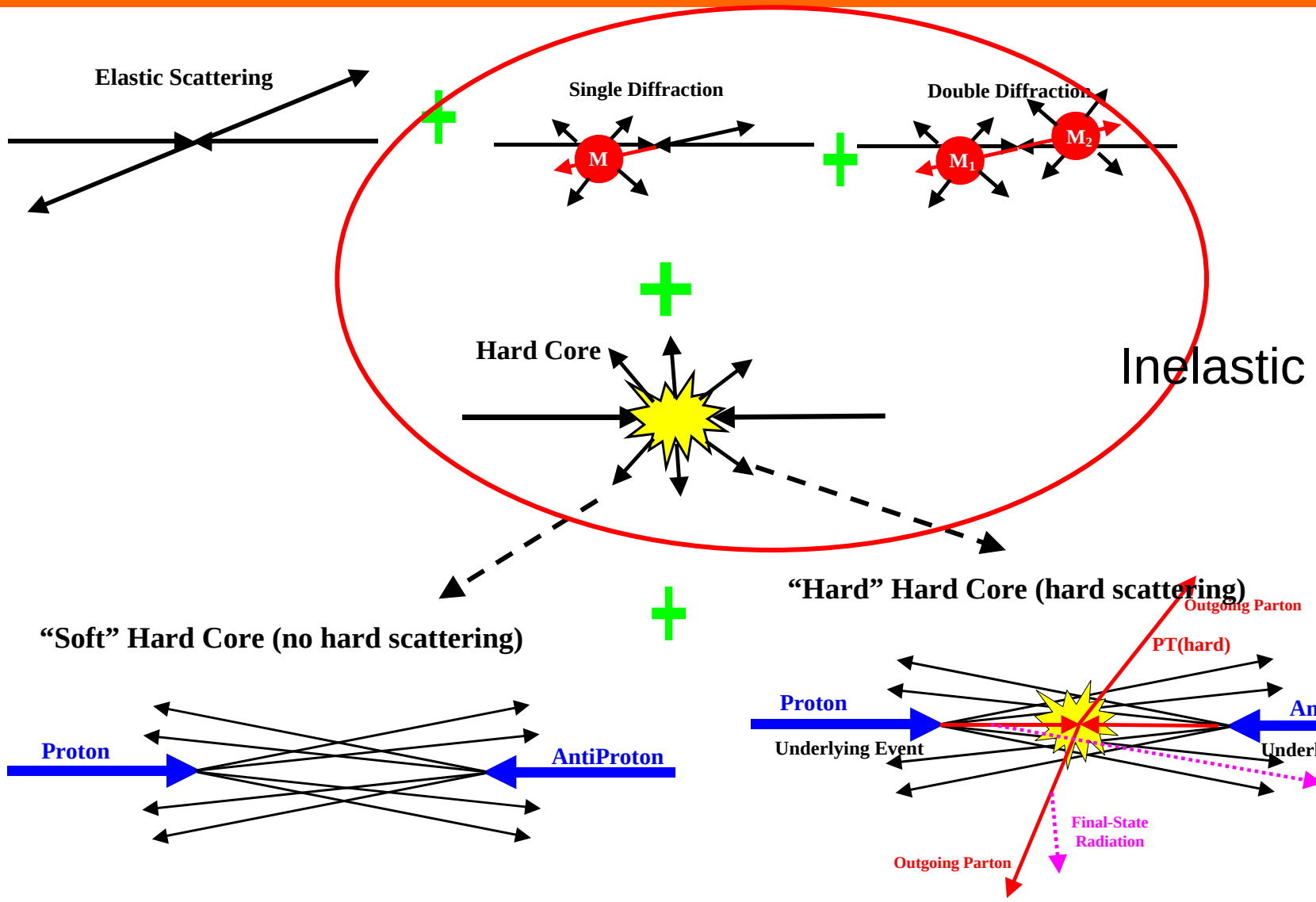
Nhit distributions vs. threshold

Data = red Simulation = black

MBR full inelastic



The total p-pbar cross-section



ε_α from CLC simulations

$$\sigma_{tot} \sim 81.9 \pm 2.3\,\text{mb} \rightarrow \sigma_{inel} \sim 61.9 \pm 1.4\,\text{mb} \rightarrow \begin{cases} \sigma_h \sim 44.5 \pm 1.3\,\text{mb} & \text{hard core} \\ \sigma_d \sim 10.3 \pm 0.5\,\text{mb} & \text{diffractive} \\ \sigma_{dd} \sim 7.0 \pm 0.5\,\text{mb} & \text{double diffractive} \end{cases} \quad \text{MBR}$$

$$\sigma_{tot} \rightarrow \sigma_{el} \quad \text{(0 acceptance)}$$

- Acceptance: $\varepsilon^{clc} = \dfrac{\varepsilon^h \cdot \sigma_h + \varepsilon^d \cdot \sigma_d + \varepsilon^{dd} \cdot \sigma_{dd}}{\sigma_{inel}}$

- From CLC MC simulation alone:

$$\varepsilon^h = 88.6\,(0.5)\,\%$$

$$\varepsilon^d = 9.1\,(0.4)\,\%$$

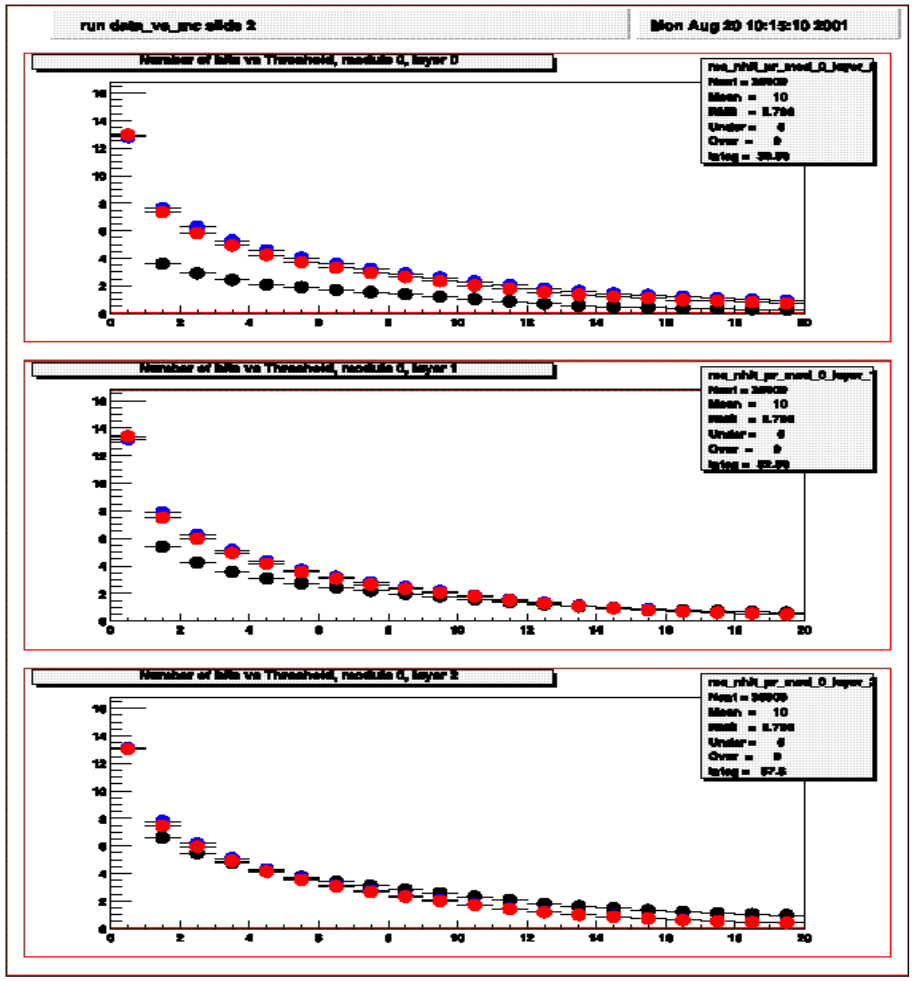
$$\varepsilon^{dd} = 31.8\,(0.7)\,\%$$

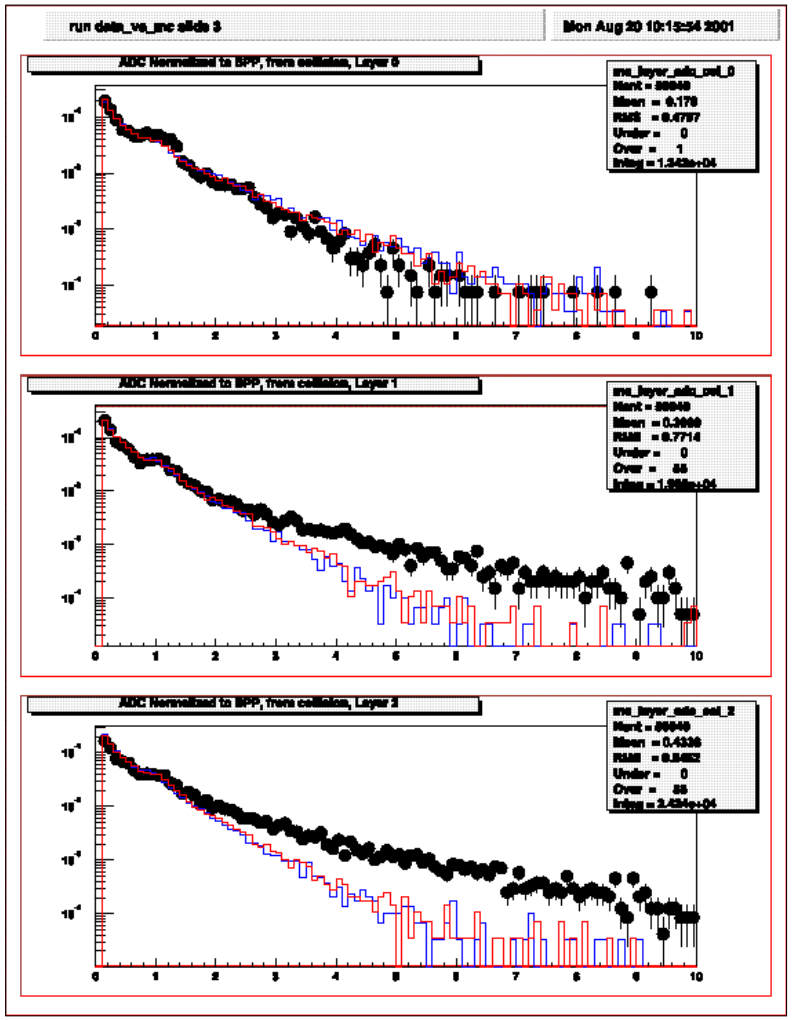
$$\Rightarrow \quad \varepsilon_\alpha^{clc} \sim 68\ \% \qquad \sigma_\alpha^{clc} = \sigma_{in} \cdot \varepsilon_\alpha^{clc} \sim 42\ \text{mb}$$

Q: How do we estimate the uncertainty on ε_α ???

Delta ε_α from simulations

- Use [very] wrong geometry → 5% change in acceptance





- Working on variations about new baseline…

ε_α from CLC+plug simulation and data

- CLC acceptance using a reference detector ($\varepsilon_R \rightarrow 100\%$)
- Expect uncertainty in ε_α ~proportional to (1- ε_α)…

$$\varepsilon_{clc} = \left(\frac{\varepsilon_{clc}}{\varepsilon_R} \right) \cdot \varepsilon_R$$

Measure experimentally — Find from simulation

- From simulations: CLC+PLUG: $\varepsilon_R \sim 94\%$
- From data: $\varepsilon_{clc} / \varepsilon_R \sim 67\%$

- Used 500 ADC thresholds in CLC
- Used 3 GeV threshold in plug
- East and West coincidence in both
- CLC+ plug acceptance in MC = 94%

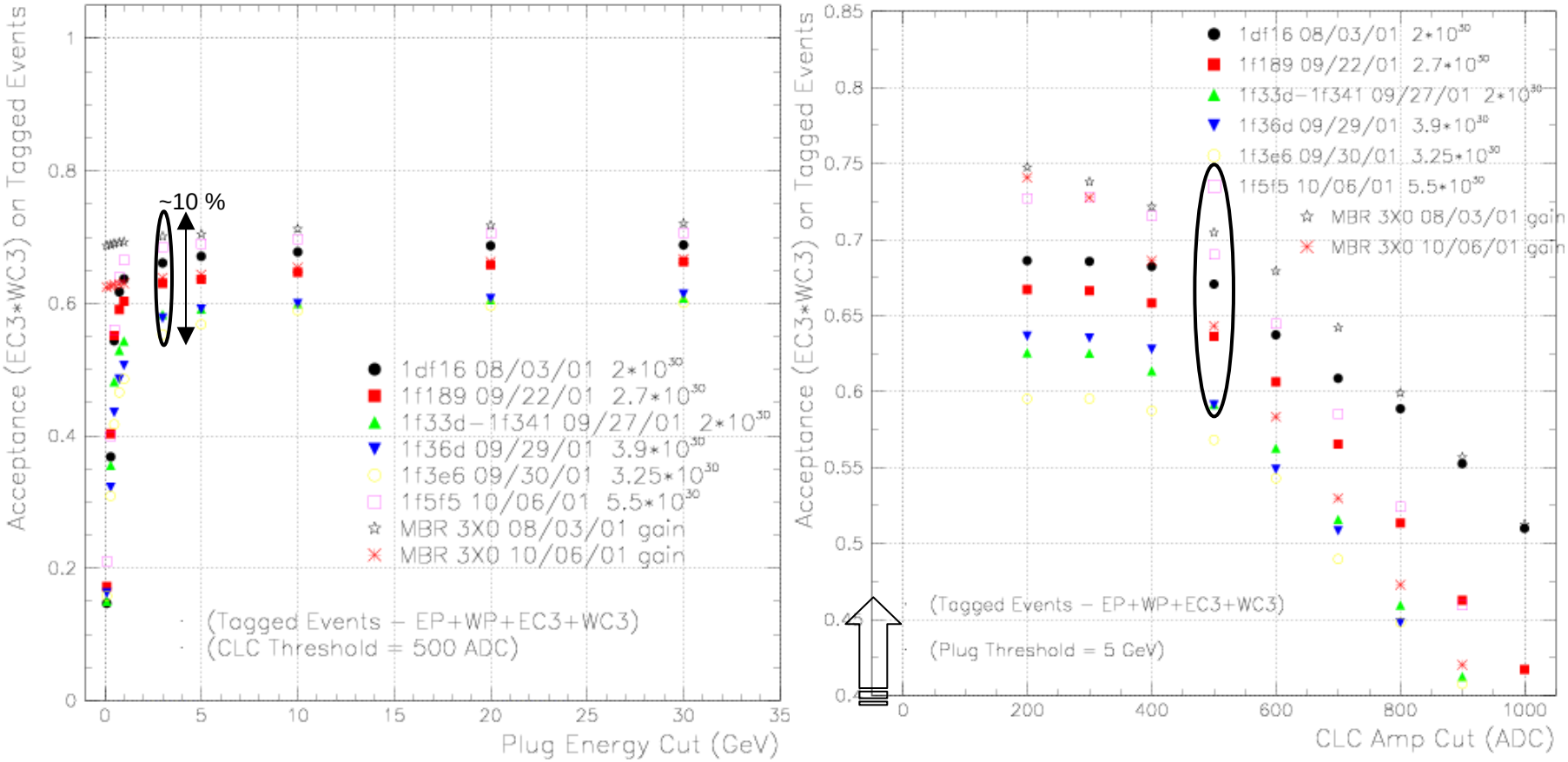
$$\varepsilon_\alpha^{clc} \sim 63\ \%$$

$$\sigma_\alpha^{clc} = \sigma_{in} \cdot \varepsilon_\alpha^{clc} \sim 39\ \text{mb}$$

- ~7 % difference with pure CLC simulation (ε_α~68%) .

Q: How do we estimate the uncertainty ???

Old studies for $\varepsilon_{clc}/\varepsilon_R$



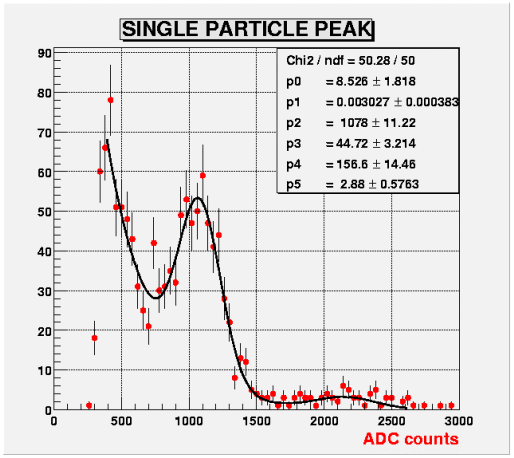
- Lots of room for improvement:
  - Spp fits not optimal: bcknd modeling, low stats, large variations
  - Plug info not well understood, no real cleanup, old reconstruction
  - Will be redone soon → take the 10% penalty for now…

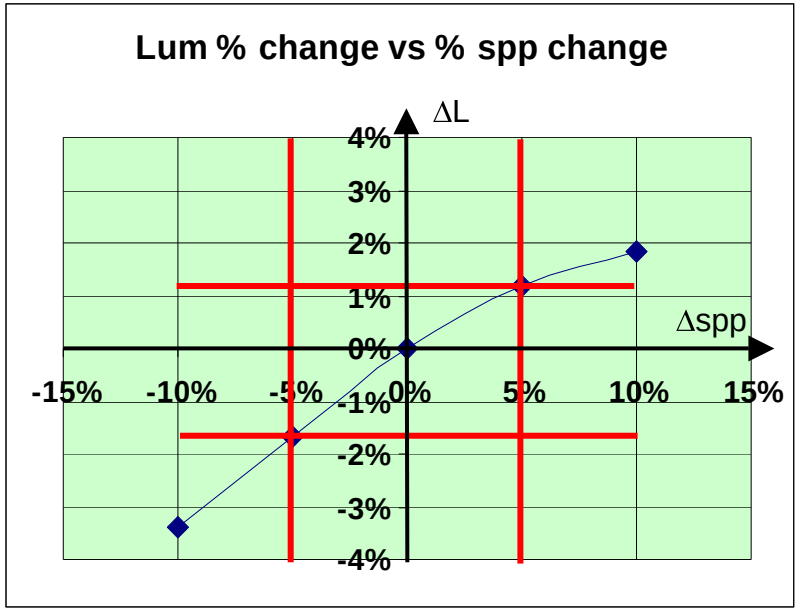
Syst. Uncertainty due to SPP determination

- ε_α is determined from simulation for a fixed set of SPP's measured from the data.
- Gain changes etc. will yield a new set of SPP's
- Statistical variations in SPP fitting procedure (Gaussian) will average out to zero in large samples

  → no uncertainty incurred
- If spp fitter pulls systematically the peaks up or down, we will incur in a syst. uncertainty in the determination of the acceptance for that "gain".
- Use MC simulation to determine % change in acceptance (same % change in Lum) as a function of % change in SPP
- Estimate possible syst. uncertainty in SPP from plot.

$$\Delta L / L \leq 1.5\%$$



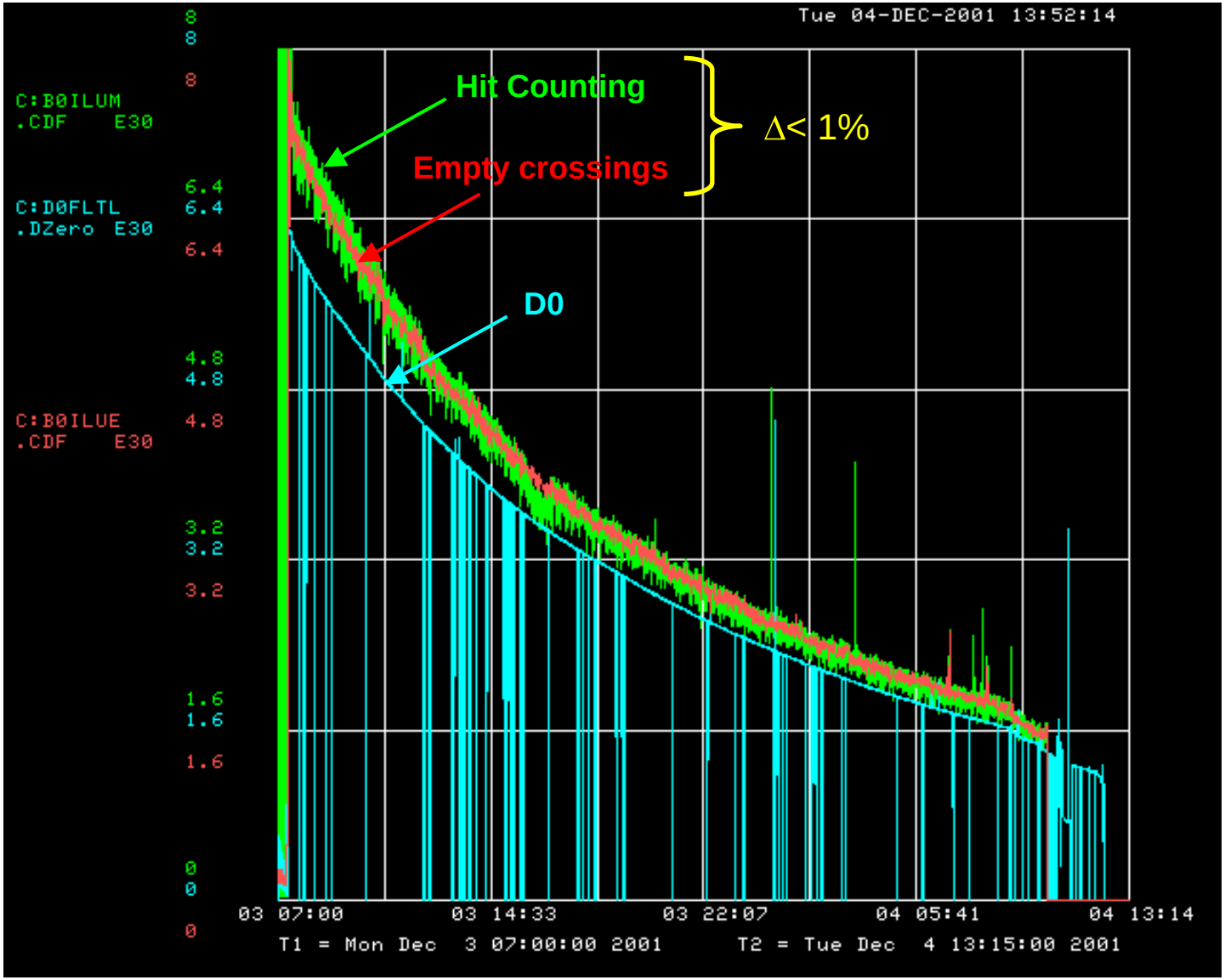


Cross- check: Luminosity by counting empty crossings

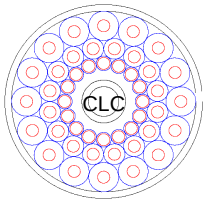
"empty" = bunch crossings with no PPbar interactions

- probability of empty crossings:
  - *full acceptance detector:* $P_0(\mu) = e^{-\mu}$
  - *"real" detector:* $\tilde{P}_0(\mu, \varepsilon_0, \varepsilon_1) = e^{-\mu(1-\varepsilon_0)}(2 \cdot e^{\mu\varepsilon_1} - 1)$
    - $\rightarrow \varepsilon_0$ **- probability to have no hits in CLC (~10%)**
    - $\rightarrow \varepsilon_1$ **- probability to have hits exclusively in one CLC module (~12%)**
  - *For ~low lum:* $P_0(\mu) = e^{-\varepsilon_\alpha \mu}$
  - *Saturates at medium lum ~ 5*10**31*

Empty crossing vs Hit counting



Can assign < 1 % uncertainty to Nhit



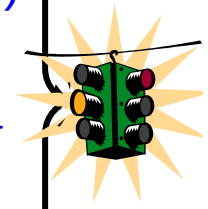
Uncertainty p- pbar cross- sections

Process (mb)	CDF meas. @ 1.8 TeV	E811 Exp.	D0 Exp.	CDF extrap. @ 2.0 TeV	New MBR MC
σ_{tot}	80.03 (2.24)	71.71 (2.02)	75.01 (2.85)	81.90 (2.30)	[81.9]
σ_{el}	19.70 (0.85)	15.79 (0.87)	17.67 (1.33)	21.50 (0.90)	[20]
σ_{in}	60.33 (1.40) 2%	8% 55.92 (1.19) 2%	57.55 (1.56)	60.40 (1.40)	61.90 (1.40)
σ_{hc}	[51]		46.69 (1.63)	[51]	44.54 (1.30)
σ_{sd}	9.46 (0.44)	8.1 (1.7) E710	9.57 (0.43)	10.00 (0.45)	10.30 (0.50)
σ_{dd}	ϕ	ϕ	1.29 (0.20)	ϕ	7.00 (0.50)

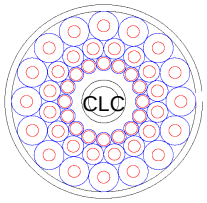
Summary CLC Luminosity Uncertainty

of course preliminary !

- Online → Offline transfer < 2 %
  - Will go away with more automated lum reconstruction.
- ε_{α}
  - Estimate from CLC simulation alone < 5% (from wrong vs "right" sim.)
  - Will be re-done with more realistic variations
  - Estimate uncertainty from CLC+PLUG method < 10% (from old data with…
  - Will be re-done with:
  - Should become of order close to (1- ε_R) ~ few %



- Estimate N_hit uncertainty < 2%
  - From ratio of hit counting/empty crossing
  - From extrapolating data from high to low lum
- Estimate uncertainty due to PMT gain changes and not updating at shorter intervals < 2%
  - Expect to go away with more stable PMTs
- Uncertainty due to SPP determination <1.5%



CLC Luminosity Uncertainty
quite preliminary !

- Total uncertainty due to measurement < 10%
- CDF's uncertainty in inelastic cross section = 2.3 %

→Quoted total uncertainty ~ 10%

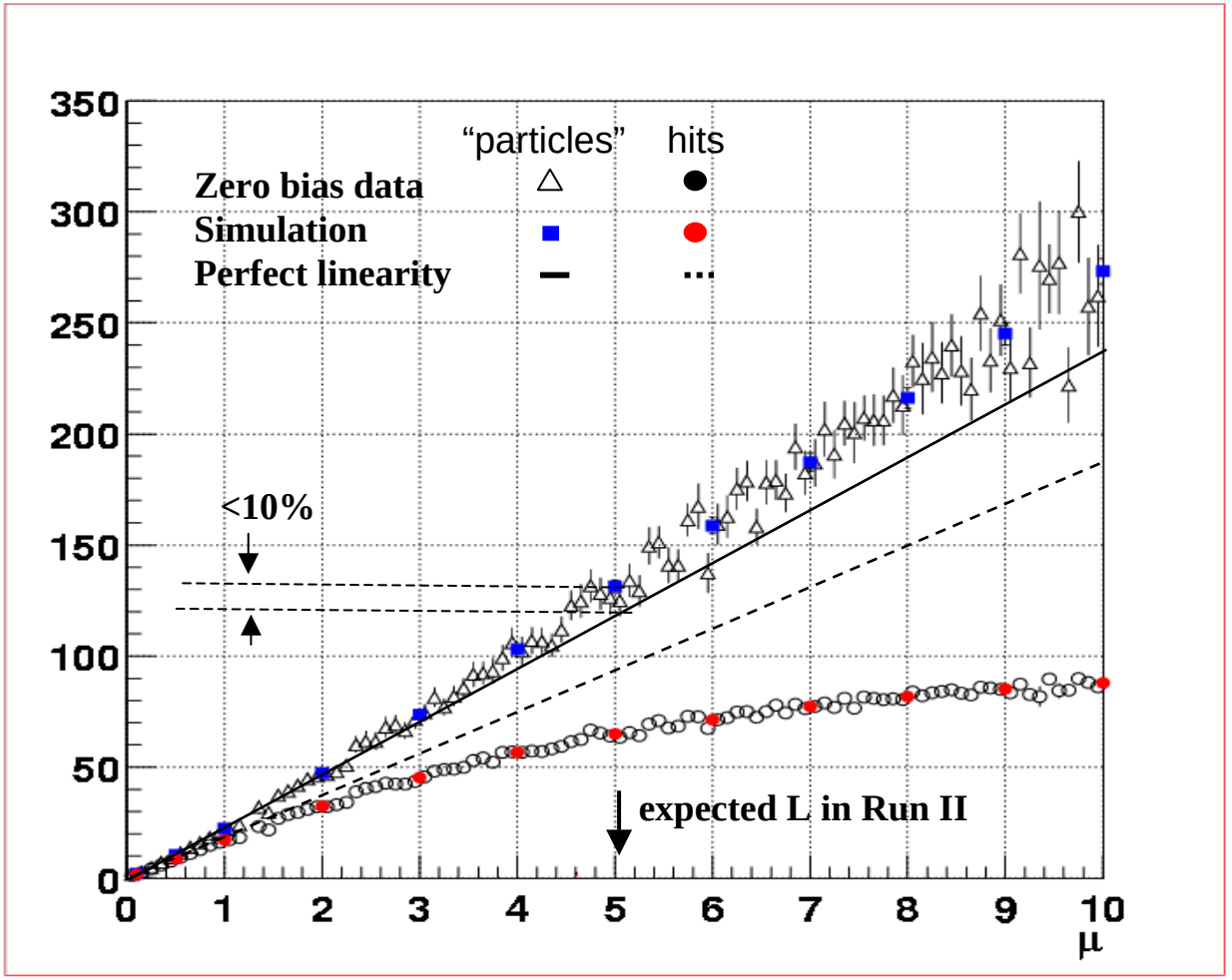
- More:
  - Can we go to high luminosity with these methods?
  - Cross-check with W's

Measuring Luminosity at High Lum

Experiment:
Construct bunch crossings with large μ superimposing zero bias events at low μ.

Hits:
Average number of hits

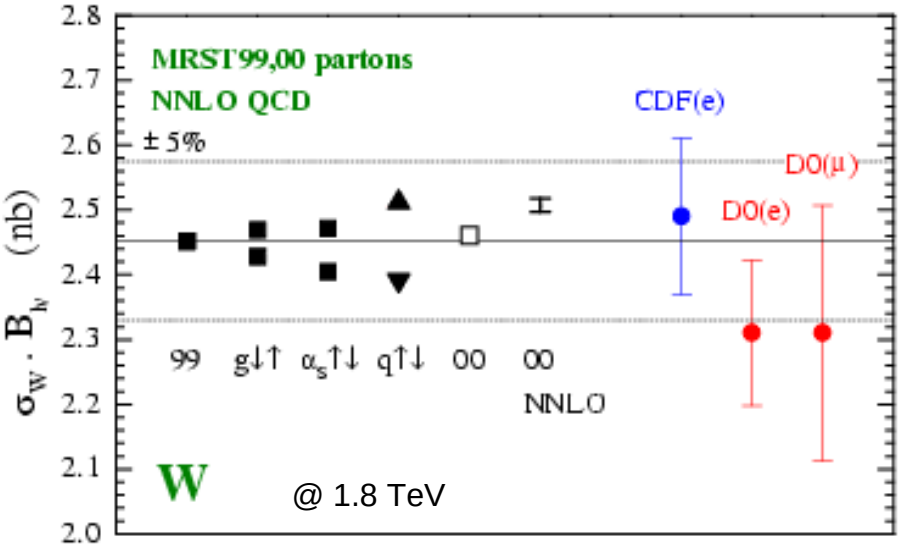
"Particles":
Total amplitude / Ao
Ao = amplitude of single particle peak



Precise high luminosity measurements are feasible !!!

Luminosity with W→lep, nu

- Complementary L measurement with different systematic error
- Cross-section @ 1.96 TeV = 2.6 nb with 5% theoretical uncertainty (Ellis & Stirling & Webber)
  - ***PDF, EWK param, scale variation, higher order corrections***
- Expected rate @L=2 10^{32} ~ 0.5Hz
- Trigger+selection efficiency ~25%
  → detected W rate ~0.1Hz
- Good for abs. normalization of "chunks of data
- Not trivial:



$$N_W = L \cdot \sigma(p\bar{p} \to WX) \cdot B(W \to e\nu) \cdot \varepsilon_{\not{E}t} \cdot \varepsilon_{E_T,\eta} \cdot \varepsilon_{Trk} \cdot \varepsilon_{P_T} \cdot \varepsilon_{Iso} \cdot \varepsilon_{ID} \cdot \varepsilon_{Event} \cdot \varepsilon_{Trig}$$

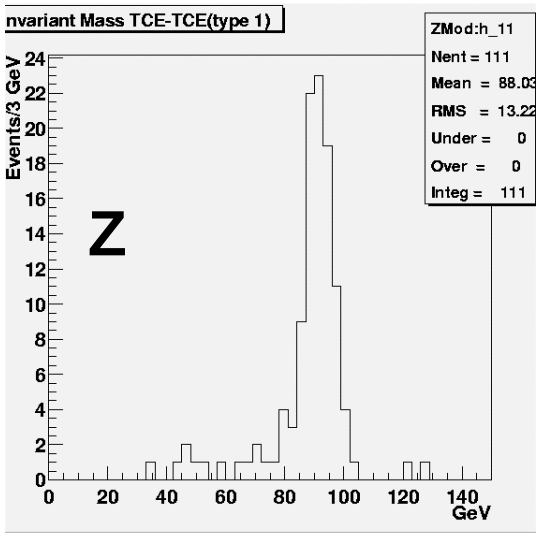
- + backgrounds …

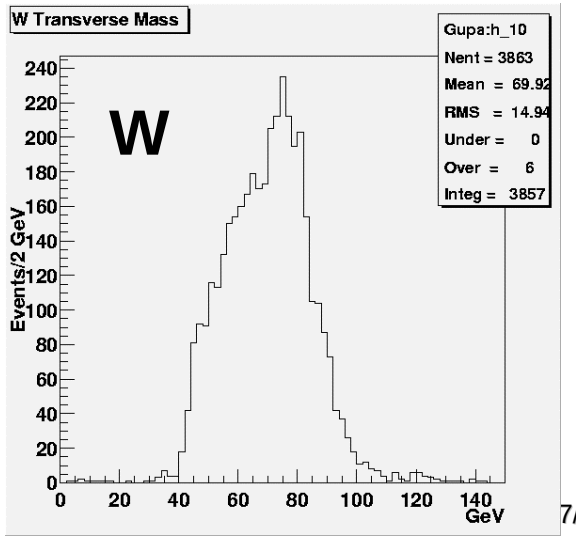
Luminosity with W's

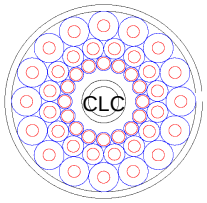
- **Lum group efforts:**
  - Pursue ~standard analysis (W+X)
  - Find simpler selection criteria
    - Yield smaller systematic uncertainties
    - Simple to monitor over time
      - Choice of lepton
      - Simple particle ID
      - Low backgrounds
    - Simple to monitor over time
  - Explore using:

$$\sigma(W+0j) = \sigma(W+X) \cdot \frac{\sigma(Z+0j)}{\sigma(Z+X)}$$

      - Smaller backgrounds
      - Some systematics may cancel in ratio







Luminosity with W's

- **Stream B high- Et electrons (bhel01)**
- **Filesets CA5486.* & CA65627.***
- **Selection criteria"**
  - Central Et electron > 20 GeV
  - Track Pt > 10 GeV
  - Met > 20 GeV
  - ~Standard electron ID
  - Pythia + full sim for geom+kin accept.
  - Z→e,e for electron ID + trk efficiency
- **Integrated Lum = 5.53 pb- 1**

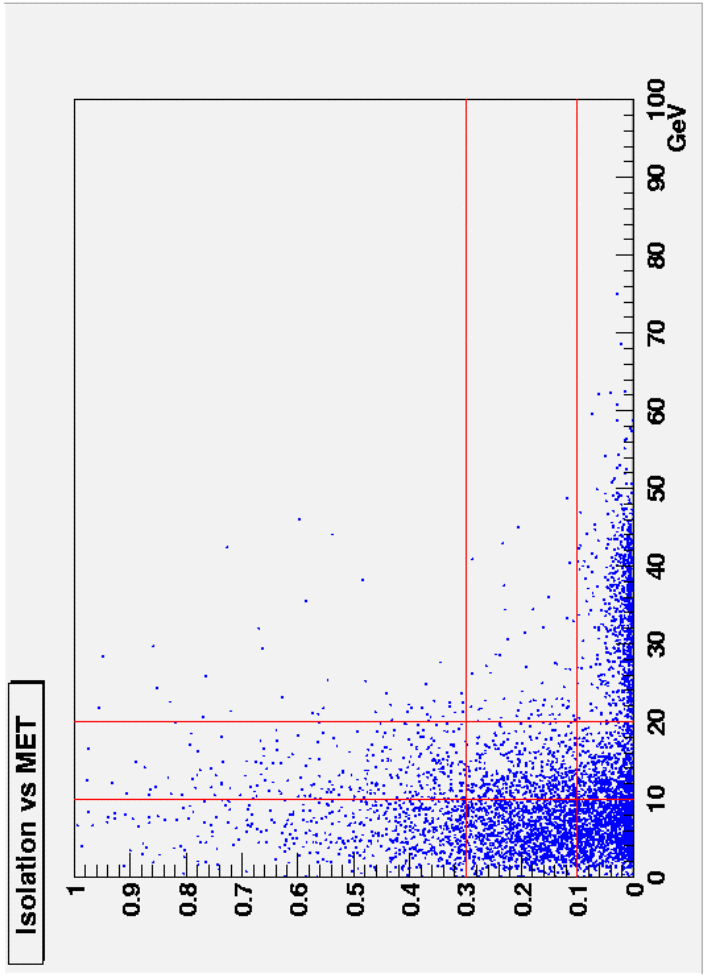
Luminosity with W's

Selection	Efficiency %
Geom + Kin (MC)	32.0 (1.0)
Track finding (data)	99.2 (0.8)
Track Pt (MC)	97.8
Ele ID (data)	81.5 (2.7)
Trigger (estimate)	97 (2)
Total	24.5 (1.2)

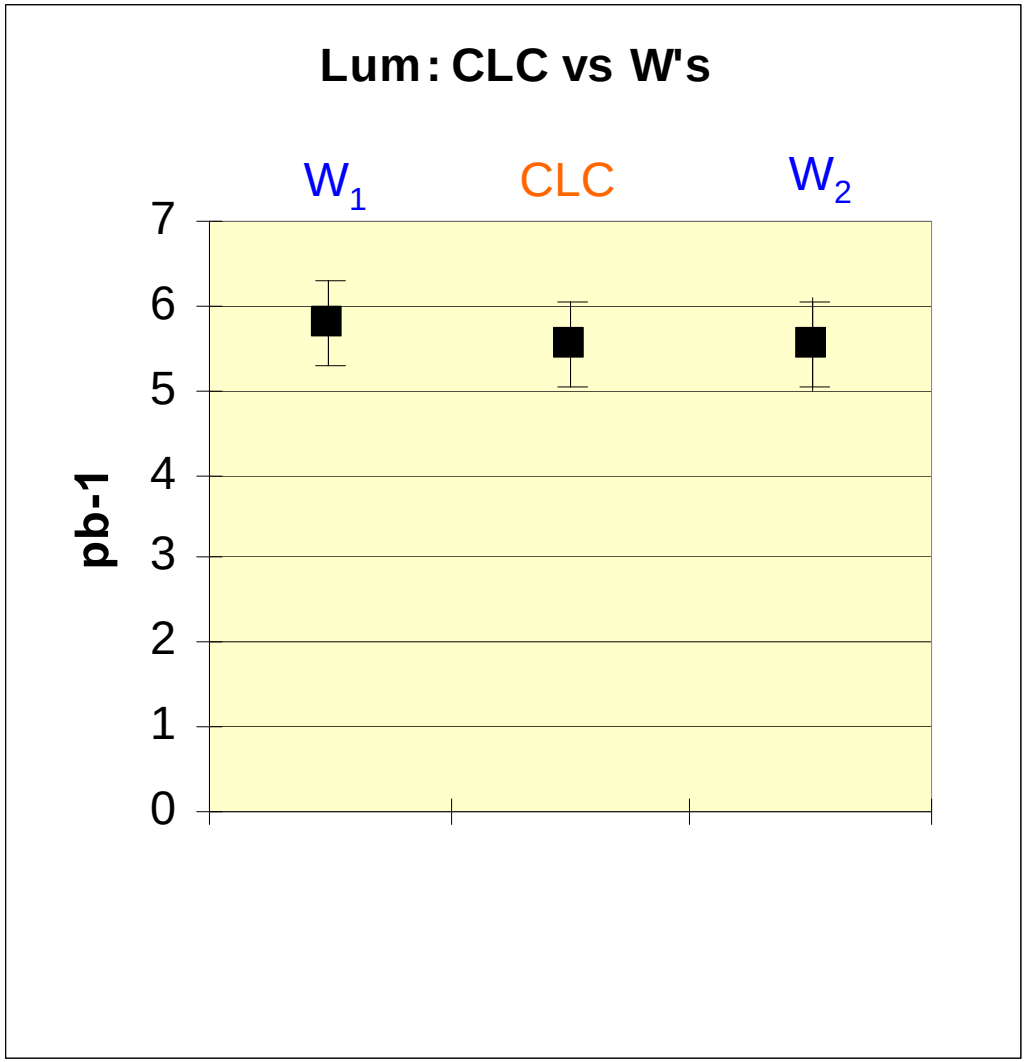
- **Caveats:**
  - No EM corrections
  - No VTX corrections
  - …
- **But full pass anyway**

Backgrounds

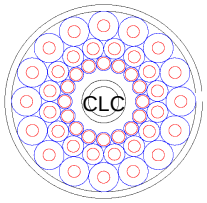
- Missing Et vs Iso
- 3863 before
- 3541 after
  - *~8% background*
  - *Consistent with PRL (1996)*
  - *~1.5 % uncertainty in cross-section or lum*



Towards absolute normalization



$W_{1,2}$ = two different electron ID cuts



Summary and plans

- Established all Lum measurements and accounting
- Uncertainty at the 10% level
- Working on nailing down absolute normalization systematics
  - Generator, Simulation, material, thresholds, etc. etc.
- Working with W's for cross-checks
  - Looks good so far
- Expect absolute normalization uncertainty below 5% at all Luminosities
- It's been harder with changing gains
  - Strong effort in calibrations and operations
  - Will replace PMTs with [hopefully] more robust ones
- Implement and test high lum algorithms later on
  - Particle counting
  - Time clusters

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